Contamination of drinking-water by arsenic in Bangladesh: a public health emergency

Allan H. Smith,[1] Elena O. Lingas,[2] & Mahfuzar Rahman[3]

The contamination of groundwater by arsenic in Bangladesh is the largest poisoning of a population in history, with millions of people exposed. This paper describes the history of the discovery of arsenic in drinking-water in Bangladesh and recommends intervention strategies. Tube-wells were installed to provide "pure water" to prevent morbidity and mortality from gastrointestinal disease. The water from the millions of tube-wells that were installed was not tested for arsenic contamination. Studies in other countries where the population has had long-term exposure to arsenic in groundwater indicate that 1 in 10 people who drink water containing 500 μg of arsenic per litre may ultimately die from cancers caused by arsenic, including lung, bladder and skin cancers. The rapid allocation of funding and prompt expansion of current interventions to address this contamination should be facilitated. The fundamental intervention is the identification and provision of arsenic-free drinking water. Arsenic is rapidly excreted in urine, and for early or mild cases, no specific treatment is required. Community education and participation are essential to ensure that interventions are successful; these should be coupled with follow-up monitoring to confirm that exposure has ended. Taken together with the discovery of arsenic in groundwater in other countries, the experience in Bangladesh shows that groundwater sources throughout the world that are used for drinking-water should be tested for arsenic.

Keywords: Bangladesh; arsenic poisoning, prevention and control; arsenic poisoning, therapy; water pollution, chemical, prevention and control; water treatment; environmental monitoring.

Voir page 1100 le résumé en français. En la página 1101 figura un resumen en español.

Introduction

Bangladesh is grappling with the largest mass poisoning of a population in history because groundwater used for drinking has been contaminated with naturally occurring inorganic arsenic. It is estimated that of the 125 million inhabitants of Bangladesh between 35 million and 77 million are at risk of drinking contaminated water (*1, 2*). The scale of this environmental disaster is greater than any seen before; it is beyond the accidents at Bhopal, India, in 1984, and Chernobyl, Ukraine, in 1986. This paper suggests guidelines for responding when a population is exposed to arsenic, and it is based on information from several visits to Bangladesh made by Allan H. Smith as a consultant for the World Health Organization between 1997 and 1998 (*3–5*).

In 1983, the first cases of arsenic-induced skin lesions were identified by K.C. Saha then at the Department of Dermatology, School of Tropical Medicine in Calcutta, India (*6*). The first patients seen were from West Bengal, but by 1987 several had already been identified who came from neighbouring Bangladesh. The characteristic skin lesions included pigmentation changes, mainly on the upper chest, arms and legs, and keratoses of the palms of the hands and soles of the feet (Fig. 1). After ruling out other causes, water sources used by the patients were analysed, and the diagnosis of arsenic-caused disease was confirmed. The primary drinking-water sources for the patients were tube-wells, which drew water from underground aquifers (Fig. 2) (*6*).

Tube-wells have been used in Bangladesh since the 1940s (*7*). However, the problem of arsenic-contaminated water has only recently come to light due to the increasing number of tube-wells used over the past 20 years and the subsequent increase in the number of individuals drinking from them. Historically, surface water sources in Bangladesh have been contaminated with microorganisms, causing a significant burden of disease and mortality. Infants and children suffered from acute gastrointestinal disease resulting from bacterial contamination of stagnant pond water. Consequently, during the 1970s the United Nations Children's Fund (UNICEF) worked with the Department of Public Health Engineering to install tube-wells to provide what was presumably a safe source of drinking-water for the population. These wells consist of tubes that are 5 cm in diameter that are inserted into the ground at depths of usually less than 200 m. The tubes are then capped with a cast

[1] Professor of Epidemiology, 140 Warren Hall, School of Public Health, University of California, Berkeley, Berkeley, CA 94720-7360, USA (email: ahsmith@uclink4.berkeley.edu). Correspondence should be addressed to this author.

[2] Doctoral Research Student, School of Public Health, University of California, Berkeley, USA.

[3] International Fellow, Public Health Sciences Division, International Centre for Diarrheal Disease Research in Bangladesh, Dhaka, Bangladesh; Division of Occupational and Environmental Medicine, Faculty of Health Sciences, Linköping University, Sweden.

Ref. No. **00-0751**

Fig. 1. **Skin lesions due to arsenic poisoning**

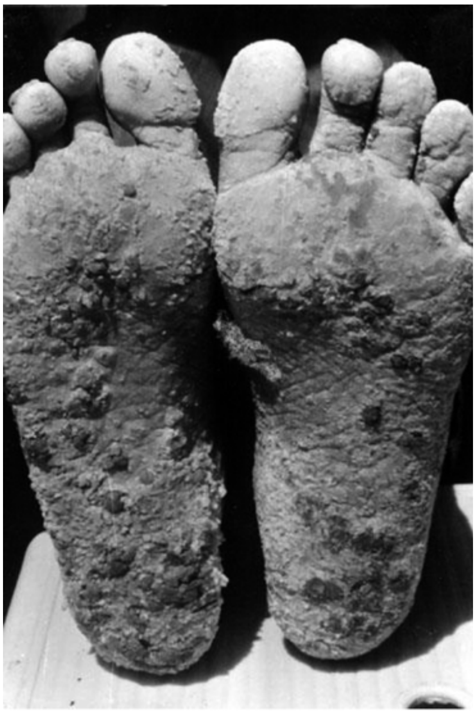

Table 1. **Percentage of groundwaters surveyed in 1998 by the British Geological Survey with arsenic levels over 50 μg/l**

District	% of groundwaters surveyed	District	% of groundwaters surveyed
Bagerhat	66	Madaripur	93
Barisal	63	Magura	19
Brahmanbaria	38	Manikganj	15
Chandpur	96	Meherpur	60
Chittagong	20	Moulvibazar	12
Chuadanga	44	Munshiganj	83
Comilla	65	Narail	43
Cox's Bazar	3	Narayanganj	24
Dhaka	37	Nawabganj	4
Faridpur	66	Noakhali	75
Feni	39	Pabna	17
Gopalganj	94	Pirojpur	24
Jessore	51	Rajbari	24
Jhalakati	14	Rajshashi	6
Jhenaidah	26	Satkhira	73
Khulna	32	Shariatpur	80
Kushtia	28	Sylhet	19
Lakshmipur	68		

iron or steel hand pump. At the time the wells were installed, arsenic was not recognized as a problem in water supplies, and therefore standard water testing procedures did not include tests for arsenic (*7*).

During the 1980s, UNICEF's support for installing tube-wells decreased because the private sector was able to supply and install millions more of them (*7*). By 1997, UNICEF indicated in its country report for Bangladesh that it had surpassed its goal of providing 80% of the population by 2000 with access to "safe" drinking-water in the form of tube-wells, ring-wells and taps (*8*). Presently, three out of four tube-wells in Bangladesh are privately owned (*7*).

Extent of exposure in the population

In Bangladesh, arsenic contamination of water in tube-wells was confirmed in 1993 in the Nawabganj district (*1*). Further testing was done in the following years; this included investigations by the Department of Occupational and Environmental Health of the National Institute of Preventive and Social Medicine. Results from various laboratories were collated in a WHO country situation report in 1996 (*9*). The institutions that provided results included the Jadavpur University in Calcutta, India, the Bangladesh Atomic Energy Commission, the Department of Public Health Engineering's laboratories in the Khulna and Rajshahi districts, and the National Institute of Preventive and Social Medicine in Dhaka. Altogether, 400 measurements were presented in the report, although contamination in some wells was measured by more than one laboratory. In about half of the measurements concentrations were above 50 μg/l (*9*), which is clearly in excess of the maximum level recommended by WHO of 10 μg/l (*10*) and greater than the maximum level of 50 μg/l permitted in Bangladesh (*7*).

To raise awareness of the seriousness of the arsenic problem in West Bengal and to draw attention to the need for studies in Bangladesh, a conference was convened in 1995 by D. Chakraborti and the School of Environmental Studies of Jadavpur University in Calcutta (*11*). In the years after the conference, the extent of the problem in Bangladesh has become clearer through additional surveys of the water and population, many of which were led by Chakraborti.

A study conducted in the Rajarampur village of the Nawabganj district, by the National Institute of Preventive and Social Medicine and the School of Environmental Studies, found that 29% of the 294 tube-wells tested had arsenic concentrations greater than 50 μg/l (*12*). Between September 1996 and June 1997, a survey was jointly conducted by Dhaka Community Hospital and the School of Environmental Studies. An examination of 265 wells in Samta village in the Jessore district found that about 91% of the wells had arsenic concentrations higher than 50 μg/l (*13*). In 1998, a British Geological Survey of 41 districts collected 2022 water samples — 35% were found to have arsenic concentrations above 50 μg/l (Table 1) and 8.4% were above 300 μg/l (*14*). Based on population density measured in 1998, this group estimated that the number of people exposed to arsenic concentrations above 50 μg/l was about 21 million. This number would be approximately doubled if WHO's standard of 10 μg/l were adopted. Further studies conducted by the

School of Environmental Studies and the Dhaka Community Hospital found that 59% of the 7800 groundwater samples had arsenic concentrations greater than 50 µg/l (*15*).

In 1997 a project designed to establish the extent of the problem in a sample population was authorized by the government of Bangladesh. Two hundred villages that had already been identified as having arsenic-contaminated tube-wells were surveyed by the Rapid Action Programme. These villages had a combined population of 469 424. About 62% of the 32 651 tube-wells sampled had concentrations greater than 100 µg/l (*16*).

Surveys of the effects on the population's health have occurred concurrently with the previous studies of groundwater contamination. From December 1996 to January 1997, a three-week survey was conducted by the Dhaka Community Hospital and the School of Environmental Studies. The survey team visited 18 affected districts. Of the 1630 adults and children examined, 57.5% of them had skin lesions due to arsenic poisoning (*11*). In another study, approximately one-third of the 7364 patients examined had skin lesions due to arsenic (*17*).

The population of the 42 affected districts was 76.9 million. These studies do not imply that the entire population is drinking contaminated water. A recent report from the World Bank has estimated that 20 million inhabitants of Bangladesh may be drinking arsenic-contaminated water (*18*).

In the 200 villages surveyed by the Rapid Action Programme, 1802 of 469 424 people were found to have arsenic-induced skin lesions. During the same period a more detailed study of four villages with arsenic-contaminated tube-wells was conducted, and 1481 adults were interviewed and examined (*19*). Of these, 430 were found to have skin lesions.

The actual extent of the contamination and the number of people with skin diseases caused by arsenic might be many times higher than is currently estimated. For comparison, it has been estimated that in West Bengal the number of people exposed to arsenic is 1.5 million, and one estimate of the number of patients with arsenicosis exceeds 200 000 (*20, 21*). Since the estimate of those who may be drinking arsenic-contaminated water in Bangladesh is in the tens of millions, it is reasonable to expect that unless exposure ends the number of people with arsenicosis will eventually far exceed the number observed in West Bengal. Although all wells and all villagers have not been systematically tested and examined, this should not delay action. The evidence that has accumulated since 1997 has only confirmed that this is a public health threat of great magnitude (Box 1).

Long-term health effects of exposure

The health effects of ingesting arsenic-contaminated drinking-water appear slowly (Box 2). For this reason, a more important issue than the number of patients who currently have arsenic-caused diseases is the number who will develop these diseases in the future as a result of past and continuing exposure to arsenic. Large numbers of tube-wells were installed in Bangladesh approximately 5 to 20 years ago. If the population continues to drink arsenic-contaminated water, then a major increase in the number of cases of diseases caused by arsenic may be predicted.

Fig. 2. **Children near a tube-well disconnected due to contamination of water with arsenic**

WHO 00230

Skin lesions

The latency for arsenic-caused skin lesions (i.e., the time from first exposure to manifestation of disease), in particular keratoses, is typically about 10 years (*22*). In the 1997 consultancy, it was found that the youngest individuals with skin lesions caused by arsenic were about 10 years old. Other studies have shown that skin lesions also occur in children younger than 10 years (*23*). It was also found that in adults, exposures commenced approximately 10 years before they stated the skin lesions began to appear. In some instances, the apparent latency for the appearance of skin lesions from the time of first exposure to contaminated water from the tube-well currently in use was much shorter, but as no measurements were available for water from previously used tube-wells, a short latency from first exposure could not be inferred. However, latency that is shorter or longer than 10 years may occur, and the rapidity of the appearance of skin lesions appears to be dose dependent (*22*). Further studies of the latency and patterns of occurrence of skin lesions are needed and these will require careful interviewing of participants about their current and past exposures.

Box 1. **Magnitude of arsenic poisoning in Bangladesh**

Population of Bangladesh:	125 million
Total population in regions where some wells are known to be contaminated:	35–77 million
Maximum concentration of arsenic permitted in drinking-water according to WHO recommendations:	10 μg/l
Maximum concentration allowed in Bangladesh:	50 μg/l (similar to many countries worldwide)
Number of tube-wells sampled by the British Geological Survey (1998):	2022
– Proportion of wells with arsenic concentrations >50 μg/l:	35%
– Proportion of wells with arsenic concentrations >300 μg/l:	8.4%

Box 2. **Long-term health effects of exposure to arsenic**

Skin lesions
Skin cancer
Internal cancers
  Bladder
  Kidney
  Lung
Neurological effects
Hypertension and cardiovascular disease
Pulmonary disease
Peripheral vascular disease
Diabetes mellitus

Cancer

Skin cancer. Small numbers of cases of skin cancer have started to appear. Since the typical latency is more than 20 years after the beginning of exposure, the fact that only a small number have been found provides little reassurance about the future incidence of skin cancer. A study of a large population in Taiwan found a clear dose-response relationship between arsenic concentrations in drinking-water and the prevalence of skin cancer (*24*). In this study, the average concentration of arsenic in water was about 500 μg/l, and by age 60 more than 1 in 10 had developed skin cancer. The lifetime risk of developing skin cancer from the intake of 1 μg • kg body weight $^{-1}$ • day $^{-1}$ (roughly equivalent to 1 litre per day at concentrations of 50 μg/l) of arsenic in water ranges from 1 per 1000 to 2 per 1000 (*25*). Though large numbers of skin cancers have been reported in Taiwan, the future burden of arsenic-caused skin cancer in Bangladesh is uncertain. Differences in susceptibility between the populations of Taiwan and Bangladesh may exist that only time and further study will identify. However, as yet there is no evidence to indicate that the long-term risks of skin cancer would be any lower in Bangladesh than in Taiwan.

Mortality from internal cancers. In other countries, the main causes of death associated with chronic ingestion of arsenic in drinking-water are internal cancers; skin cancers are not usually fatal if treated appropriately. Dramatic increases in mortality from internal cancers have been reported in Taiwan (*26–28*) and Chile (*29*). In Taiwan, populations exposed to high concentrations of arsenic in their drinking-water, containing an average of 800 μg/l of arsenic, had estimates of their relative risk of bladder cancer in the order of 30–60 (*27, 30*). In Region II of northern Chile, 5–10% of all deaths occurring among those over the age of 30 were attributable to arsenic-caused internal cancers, in particular bladder cancer and lung cancer (*29*). Average exposures were in the order of 500 μg/l (0.5 mg/l) over 10–20 years; exposure decreased in subsequent years after remediation efforts were introduced (*29*). Long latency was apparent, and increases in mortality continued for 40 years after the highest exposures began (*29*). In Argentina, a mortality study in the arsenic-exposed region of Córdoba found increased risks of bladder and lung cancer among men and women from 1986 to 1991, although concentrations were lower (average 178 μg/l) than in Taiwan and Chile (*31, 32*).

Using the current US Environmental Protection Agency standard of 50 μg/l, it has been estimated that the lifetime risk of dying from cancer of the liver, lung, kidney or bladder while drinking 1 litre a day of water containing arsenic at this concentration could be as high as 13 per 1000 persons exposed (*30*). Using the same methods, the risk estimate for 500 μg/l of arsenic in drinking-water would be 13 per 100 people (*33*). In its latest document on arsenic in drinking-water, the US National Research Council concluded that exposure to 50 μg/l could easily result in a combined cancer risk of 1 in 100 (*34*).

Although specific estimates of the current and future health effects of arsenic exposure are uncertain, in the case of Bangladesh it can be inferred that since there are many people who currently have skin lesions caused by ingesting arsenic, many more cases will occur if exposure continues; based on what is known about the relationship between ingestion and the development of internal cancers, it is reasonable to expect marked increases in mortality from internal cancers once sufficient latency has been reached. It is also reasonable to expect marked increases in the incidence of the other health effects listed in Box 2.

Classifying arsenic in drinking-water as a public health emergency

Classifying contamination of groundwater by arsenic as a public health emergency would facilitate the rapid allocation of funding and the prompt expansion of interventions. Issues central to the argument in favour of an emergency response are listed in Box 3.

Arsenic exposure may be mitigated in a relatively straightforward manner. However, in Bangladesh the situation is complicated by the weak

Box 3. **Arsenic-contaminated drinking-water: a public health emergency**

- Arsenic exposure in Bangladesh is widespread and involves thousands of wells
- Estimates indicate that at least 100 000 cases of skin lesions caused by arsenic have occurred and there may be many more
- If exposure continues, skin lesions will continue to occur
- Skin lesions are unpleasant and may be debilitating
- Skin lesions are occurring in children aged 10 years and younger
- Large numbers of cancers are predicted to occur in the future, including fatal internal cancers
- The cause is known: each day of continued exposure increases the risk of morbidity and death
- Sustained drinking of water containing 500 μg/l of arsenic may result in 1 in 10 people dying from arsenic-related cancers
- Unlike other major health problems experienced in Bangladesh, arsenic-caused diseases can be eradicated at relatively low cost

economy and the need to rely largely on external aid to resolve public health problems. There are also significant difficulties in communication and transportation within the country that create obstacles for community education and intervention programmes. Nevertheless, in contrast to diseases like malaria, cholera and tuberculosis, which require a more complex public health response, the response to arsenic contamination is clear-cut: provide arsenic-free water. Although the precise extent of the problem is not known, this does not invalidate the need for an emergency response. The extent of the problem may be more accurately determined during the course of the response. The health of the population is at risk and relief cannot wait for further surveys.

Emergency intervention programme

The core activity of an emergency action plan for this threat to human health should be rapid case ascertainment and immediate provision of arsenic-free water. The objectives of such a plan should be as follows: (1) to identify all cases of arsenicosis in Bangladesh; (2) the immediate identification of an interim source of arsenic-free water and commencement of implementation of the long-term solution; (3) to monitor patients' progress and compliance with interim water treatment until a long-term water source has been identified and made available; and (4) to provide care for patients, including vitamin supplementation, lotions for patients with keratoses and treatment of infections.

Strategies to reduce exposure

A short-term strategy might include five responses. Firstly, identify nearby tube-wells that have water with a low arsenic content. Secondly, provide a water filter for each household. A candle filtration system is available. It is easy to use and maintain, and this contributes to good compliance. The disadvantage is that the arsenic-loaded candles must be disposed of but this should not be a problem if the filter is used as an interim solution for a few months only. Units designed to be attached to tube-wells to remove arsenic are being tested and may prove to be an effective short-term alternative. Thirdly, provide chemicals to be used daily to remove arsenic from household drinking-water. The small packet of chemicals that can be mixed in water and left to stand overnight is very cheap and is simple to transport. The disadvantages of this strategy include the need for daily or close to daily use and the need to dispose of the sludge after each treatment. Whether people will use these chemicals needs to be evaluated. Fourthly, use surface water sources that have been treated by filtration and chlorination. Fifthly, close highly contaminated wells when a temporary water source has been identified.

Field kits should be used if they can detect contamination of water containing 100 μg/l or more of arsenic. It would be better still if they could reliably detect 50 μg/l. Since WHO's recommended maximum concentration of 10 μg/l cannot be accurately measured with a field kit, it has been proposed that samples should be sent to laboratories for testing. However, sending samples to a laboratory can cause delays to programmes in the affected communities. In contrast, using field kits that can measure concentrations of 50 μg/l provides instantaneous results and facilitates prompt action to find an alternative water source if needed (*35*).

Some interventions that involve major actions, such as treating water with chemical packets, are inexpensive as far as materials are concerned but are expensive in terms of training, monitoring and education. Treating water with alum or allowing it to stand so that arsenic settles in iron-rich water is not advisable since reducing exposure in the short-term by the order of 50% (compared with a reduction of 80–90%) does little to alter the cumulative dose on which arsenic disease risks are based, and it may delay the planning for an arsenic-free solution. For example, if a short-term intervention reduces arsenic concentrations in water by 50% for 2 years but in the process uses resources and reduces motivation, thus delaying the provision of arsenic-free water for 1 year, then there has been no health benefit from the resources used because there has been no reduction in the cumulative intake of arsenic.

Further work is needed in planning long-term intervention measures. For the moment, unless there are local contraindications, the sinking of deep tube-wells (below 200 m) and dug wells or ring-wells (20–30 m) appear to be successful options. Deep tube-wells, however, have potential problems and must be installed carefully to avoid cross-contamination from shallower aquifers. Another potential long-term solution, rain-water harvesting, also warrants attention because of the high annual rainfall in the region. However, in our view, arsenic removal treatment systems have serious problems with maintenance and the disposal of arsenic sludge, and cannot be recommended as long-term solutions.

Relief from continuing arsenic ingestion cannot wait until the necessary investigations are completed for the long-term planning of alternative water sources. From a public health standpoint, emergency interventions are best accomplished through an existing technology which has already been tested and is known to be well received at the population level. Interventions requiring adjustments to an existing behaviour (for example, using a different tube-well that is a little further away) are generally more effective than introducing interventions of a new or unfamiliar nature (for example, using chemical packets to treat household water or harvesting rain water during part of the year and using another source for the rest of the year). This is particularly true in the case of arsenic poisoning because people might find it difficult to believe that crystal clear water is responsible for disease and death. The use of alternative, non-contaminated, shallow tube-wells, and the insertion of dug wells or sinking of deep tube-wells where there are no uncontaminated shallow wells, would appear to be the interventions that best satisfy these two criteria for an emergency programme.

Simple diagnosis in the field

The diagnosis of disease caused by chronic ingestion of inorganic arsenic is usually straightforward. The most common signs are hyperpigmentation, especially on the upper chest and arms, and keratoses on the palms and soles of the feet (Fig. 1). Keratoses on the palms of hands and soles of the feet are very characteristic (except in very mild early cases). The diagnosis is confirmed if a patient with keratoses and hyperpigmentation is found to have been drinking water with a high arsenic content over a period of years.

The diagnosis of arsenic-caused disease is facilitated by the ability to rapidly assess concentrations of arsenic in water. The ideal test would be one that could be done immediately in the field. Since the purpose of such tests is to detect significant exposure, the methods used do not need to be able to detect low concentrations nor do they need to have high precision. For diagnostic purposes, it would be sufficient to detect concentrations greater than 50 μg/l or 100 μg/l. At the high concentrations often encountered in Bangladesh, precision could be relatively low. For example, if a true water concentration were 350 μg/l, for initial diagnostic purposes it would be sufficient to know that the concentration was in the range 200–600 μg/l. A field kit that uses locally made materials, which was designed by the National Institute of Preventive and Social Medicine in Bangladesh, has received good evaluations in a programme sponsored by WHO (*5*).

High accuracy and precision in water measurements make little sense when human exposure also depends on the volume of water ingested. Even with careful interviewing for 10 to 15 minutes, the volume of water ingested from a particular source over the years can only be estimated within broad ranges. If a patient drank about 2–4 l of arsenic-contaminated water per day over the past 10 years, it is clear that the current concentration of arsenic in his or her drinking-water does not have to be measured with a precision of $\pm 5\%$.

Many other signs and symptoms have been reported in those patients who have chronically ingested arsenic. In studies in West Bengal, respiratory symptoms, crepitations and liver enlargement are prevalent (*36, 37*). However, these signs are non-specific and are typically accompanied by hyperpigmentation or keratoses, or both.

Since the diagnosis of arsenicosis can usually be established by simple examination of the skin, there is no need for expensive tests or for the typical patient, who may be free from other complications, to be admitted to hospital. Examination of the patient in the field, supplemented with an analysis of the arsenic content of water samples, can suffice. The examination for skin lesions itself does not require special skills or medical training.

At very high concentrations, acute symptoms may occur long before skin lesions appear. The most common early symptoms are gastrointestinal, including diarrhoea and abdominal pain (*10*). Peripheral neuropathy may occur. Such non-specific signs and symptoms in a patient living in an arsenic-exposed region should alert the physician or nurse to investigate the sources of drinking-water.

Skin cancer caused by arsenic is usually accompanied by non-malignant skin effects. The internal cancers caused by arsenic have no special features and no special diagnostic procedures can be used.

Treatment

The basic treatment is to supply the patient with drinking-water that is free from arsenic. This is the first priority. Indeed, in the absence of good evidence for the effectiveness of other treatments, the second priority is to continue providing arsenic-free water, and the third priority is to monitor patients to ensure that they remain unexposed to arsenic. Providing arsenic-free water reduces the risk of further complications and disease caused by arsenic. There are no well-designed studies to show whether cessation of exposure leads to improvement in skin keratoses. Thus far, anecdotal interviews of patients suggests that mild to moderate keratoses do improve with cessation of exposure.

Chelation. Some physicians have been giving chelation therapy to arsenic patients in West Bengal and Bangladesh. The objective of chelation therapy is to provide the patient with a chemical to which arsenic binds strongly, and is then excreted in urine.

Providing such treatment could remove large stores of arsenic from the body in a matter of hours.

There are several problems with chelation therapy in cases of chronic arsenic exposure. The first is related to the observation that arsenic is excreted rapidly even without chelation therapy. Most of the readily available arsenic in the body will be excreted in the urine within 1 week (*38, 39*). The question is whether chelation might remove arsenic which is, for example, bound in the skin and which might without chelation only be removed slowly. This is possible but exposure to arsenic generally occurs over many years, and chelation may make little difference to the cumulative dose of arsenic that patients have received. Thus, chelation therapy is unlikely to reduce the future risk of cancer. Whether it might improve keratoses more rapidly than simply stopping exposure is unknown. This idea has some plausibility but its effectiveness has not been established.

The second problem with chelation therapy is the lack of any clinical trials that found evidence of its effectiveness (*40*). When exposure to arsenic ceases, improvement in skin lesions might occur. Thus, if a patient improves after chelation therapy it could be due to the cessation of exposure alone or to both cessation and chelation therapy. Finding that patients improve after chelation therapy does not provide evidence that the therapy itself is effective.

The third problem with chelation therapy is that it is of no benefit if the patient continues to drink contaminated water after treatment, and it may give the false impression that effects can be treated despite continued exposure. Thus, chelation therapy should not be used routinely, although careful controlled studies of chelation therapy in patients with keratoses and other arsenic effects should perhaps be undertaken.

Nutrition. Since evidence from Taiwan suggests that some nutritional factors may modify cancer risks associated with arsenic (*41*), it has been proposed that providing vitamins and improving nutrition may be of benefit to patients. In particular, vitamin A is known to be beneficial in the differentiation of various tissues, particularly the skin. If the doses given are not excessive, there are

should be tested in all patients with arsenicosis, and appropriate treatment and monitoring should be started if necessary. Patients' blood pressure should also be monitored since arsenic exposure may induce hypertension (*44*).

Ongoing monitoring

Despite some attempts to educate communities, large numbers of people continue to drink from the same contaminated water sources used before the introduction of an intervention. Other water testing programmes carried out with the aid of community health workers have indicated that community awareness increases as a consequence of the programmes (*45*). Therefore, continuing education and monitoring needs to be integrated into existing health services, whether governmental or non-governmental.

Guidelines for programmes aimed at continuing to educate and monitor populations exposed to arsenic should include advising these populations about the arsenic in drinking-water, the sources of arsenic-free water, and the importance of compliance with treatment programmes, including nutrition. Field workers should make monthly home visits to those villages that are most seriously affected. Field workers should be equipped with a continuing education plan, topical creams for keratoses, vitamin tablets, and medicines for fungal infections.

Patients should be advised where to seek additional medical care if needed. The physicians and paramedical staff serving the most affected areas should receive special training in understanding arsenic toxicity, disease outcomes and treatment options.

The possibility of continuing exposure to arsenic through water or food should be monitored through the testing of urine samples. Currently, there is no recommended field kit for urine testing. Therefore, samples should be sent to a reference laboratory equipped to measure arsenic in biological specimens.

In addition to obtaining biological samples, field workers should interview patients and ask them where they currently get their drinking-water to